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The relationship between investments in lean practices and operational performance: exploring the moderating effects of operational intellectual capital

Abstract

Purpose - Prior research has shown that operational intellectual capital (OIC) and investments in lean practices (ILP) lead to better operational performance. However, there has been no empirical studies on the synergetic effects between OIC components and ILP. More specifically, the question: can the efficacy of ILP be increased through OIC has not been studied. Accordingly, the purpose of this study is to report the empirical results of potential synergetic effects between operational intellectual capital (OIC), as a knowledge-based resource, and ILP.

Design/Methodology/approach - The empirical data used for this study was drawn from the fifth round of the Global Manufacturing Research Group (GMRG) survey project (with data collected from 528 manufacturing plants). The hypotheses are empirically tested using three ordinary least square (OLS) models.

Findings - Our findings highlight the importance of leveraging a system of complementary knowledge based resources (OIC dimensions) and addresses the need for the reformulation of lean theory in terms of the emergent knowledge-based view (KBV) of the firm. The results facilitate greater understanding of the complex relationship between ILP and operational performance. Building on the contribution of Menor et al. (2007), we argue that OIC represents a strategic knowledge based resource that is valuable, hard to imitate or substitute and when leveraged effectively, generates superior operational and competitive advantage.

Practical implications - From a managerial standpoint, this study provides guidelines for managers on how to leverage OIC to enhance the efficacy of ILP. We argue that firms consider investing in OIC to increase the return from ILP, which in turn will enhance their operational performance and provide competitive advantage. Our findings provide strong evidence of the importance of human, social and structural capital to enhance the efficacy of ILP.

Originality/value - This is the first research paper that extends the application of intellectual capital theory in lean literature, and argues that the operational intellectual capital contributes

to the efficacy of ILP. The analysis facilitates greater understanding of the complex relationship between OIC dimensions, ILP and operational performance.

Keywords: Operational intellectual capital, lean practices, operational performance, empirical research

Paper type: Research Paper

1. Introduction

Lean practices have been adopted by companies across the world and there is a considerable body of work which has investigated the relationship between lean manufacturing adoption and organisational performance (Jasti and Kodali, 2015, Negrão et al., 2016). The objective of lean manufacturing is to maximize customer value while minimizing waste. The ultimate goal of implementing lean production in an operation is to increase productivity, enhance quality, shorten lead times, and reduce cost. Negrão et al. (2016) argue that most of the research to date has focused on the technical aspects of lean (i.e. practice implementation and its effect on performance), rather than the "people" related issues. More recently, researchers have shifted their focus towards "why" lean works (or not), and in particular addressing human resource management (HRM) practices (Vivares-Vergara et al., 2016). For example, Bonavia and Marin-Garcia (2011) note that the majority of recent studies have concentrated on examining the HRM practices needed to sustain lean implementation over time, but little is known as to whether or not the HR function can have a more strategic impact on lean practices. Sparrow and Otaye-Ebede (2014) argue that in order to achieve sustainable lean implementation, companies need to focus on building dedicated and specialised knowledge and creating a broader structural grouping of intellectual capital. Similarly, Reed et al. (2006) contend that knowledge and the management of intellectual capital has become a key factor of growth and sustainability in firms, allowing them to become more adaptable and responsive. Although prior research has shown that intellectual capital (IC) leads to improved organisational performance (Menor et al., 2007, Hsu and Wang, 2012, Lu et al., 2014, Wang et al., 2014), there has been no empirical studies of how intellectual capital influences the implementation of lean practices. More specifically, the question of how specific elements of operational intellectual capital (OIC) can influence the efficacy of lean practices has not been studied.

In order to improve performance, an organization needs to continuously improve its effectiveness as well as its efficiency. This is possible only through a continuous development of organizational competencies. These capabilities are rooted in the organizational knowledge assets (Ansari et al., 2012), which build the OIC of the organizations (Menor et al., 2007, Schiuma and Lerro, 2008). In a lean implementation, we argue that three dimensions of OIC: human, structural and social capital, will enhance lean investments' performance. Given that organisations accumulate expertise in multiple cycles of knowledge processing (Lee et al., 2011), this research posits that companies need to understand how to leverage different forms of knowledge resources (i.e. OIC dimensions), in order to enhance ILP. According to Teece (2014), knowledge-based resources both explicit and tacit, form competitive advantage. These knowledge-based resources are typically stored in personnel, organizational routines, manufacturing processes and relationships across the supply chain. Eisenhardt and Santos (2003) claim that these knowledge-based resources create competitive advantage because they are rare, valuable and difficult to substitute or imitate.

Proponents of the knowledge based perspective (KBV) (Grant, 1996, Hörisch et al., 2015) posit that knowledge is the most important strategic resource of the firm. In order to sustain their performance, companies need to "manage the system of complementary resources that constitutes its knowledge base" (Menor et al., 2007: p.561). Sparrow and Otaye-Ebede (2014) assert that the interactions between operations management (OM) and human resource management (HRM) practices represent a lean philosophy and these have a synergistic effect on the operational performance. Human-related resources has been identified as key to the successful implementation of lean projects and recent studies suggest that OIC plays a critical role in sustainable competitive advantage (Bonavia and Marin-Garcia, 2011, Clegg et al., 2013). According to Ling (2013), OIC is unexplored territory, while Wang et al. (2015) argue that management of OIC has a much bigger influence on employees than previously expected and that lean implementation can depend on employees willingness to adopt these practices.

Accordingly, our study will examine the synergetic effects between OIC dimensions and ILP. Building on the contribution of Menor et al. (2007), we argue that OIC represents a strategic knowledge based resource, that is valuable, hard to imitate or substitute and when leveraged effectively, generates superior operational and competitive advantage. We adopt the Subramaniam and Youndt (2005) definition of OIC as the aggregation of all knowledge embedded in the company's operating resources. OIC comprises three forms of knowledge based resources: human capital (i.e. knowledge, experience and professional skills and abilities of the employees), structural capital (i.e. codified knowledge, databases, patents, manuals, structures, information systems and processes) and social capital (i.e. communications among people and their networks of interrelationships). Lean practices are measured as the ILP (in terms of money, time and/or people) in the previous two years. Lean implementation can be broadly described as a system that encompasses a variety of practices such as: quality management programs (i.e. TQM, six sigma), cost reduction programs (i.e. target costing), manufacturing lead time reduction programs, planning/scheduling processes and methods, processing technologies (e.g. automation, advanced manufacturing technologies), flexible workforce, supplier development, workforce training and development, integrating manufacturing and design processes, the automation of plant information flows, customer service, customer process integration and supplier process integration (Cua et al., 2001, Modarress et al., 2005, Narasimhan et al., 2006, Jayaram et al., 2008, Kull et al., 2014, Bortolotti et al., 2015, Negrão et al., 2016)

Our study will address the following research question:

Can the efficacy of investments in lean practices be increased through operational intellectual capital?

In answering this question, this paper makes three key contributions to operations management literature. Firstly, we extend the application of intellectual capital theory in operations management research, by recognising the structural, social and human dimensions of intellectual capital. Although the belief that intellectual capital leads to better organisational performance is well known, very few empirical studies have tested the impact of individual elements of intellectual capital on operational performance (Menor et al., 2007) Secondly, we build on the lean literature to argue that operational intellectual capital contributes to the efficacy of ILP (Sparrow and Otaye-Ebede, 2014) and the analysis facilitates greater understanding of the complex relationship between lean practices and operational performance. Thirdly, our research offers practitioners insights into the advantages of managing knowledge assets for improved operational performance, as well as highlighting how OIC can be leveraged to enhance operational performance generated though ILP (Wang et al., 2014).

The remainder of the paper is structured as follows: we review the relevant literature in respect of lean practices and operational intellectual capital; based on this review, we develop our theoretical framework and associated hypotheses; we describe the research methodology and data analysis, and we conclude with a discussion of the results and implications.

2. Theoretical background and hypotheses development

2.1 The Impact of lean practices on operational performance

Empirical research into lean practices has advanced over the past two decades. Lean management is a holistic business strategy that requires a change in mind set that extends beyond operations. Lean thinking emphasizes excellence through the elimination of waste and a focus on continuous improvement (Fullerton et al., 2014). The literature on lean practices is extensive and numerous empirical studies have examined the impact of lean practices on performance. Much of this empirical work supports a positive relationship between lean practices and performance (Jasti and Kodali, 2015, Negrão et al., 2016). Narasimhan et al. (2006) found that lean companies that outperform their competitors use practices such six sigma, benchmarking, in-house technology development, customer and supplier orientation, integrated product development, teams and advanced manufacturing technologies. Shah and Ward (2003) examined the key facets of lean manufacturing using 22 manufacturing practices and grouped them in four “bundles” of inter-related and internally consistent practices (just in time (JIT), total quality management (TQM), total preventive maintenance (TPM) and human resource management (HRM)). Their results provided strong support for the contribution of lean bundles to the operating performance of the plants.

However, other studies highlight a negative or non-significant relationship between lean practices and performance measures. For example, Chen and Hua Tan (2013) examined the effect of lean practices in Chinese manufacturing firms and reported that companies (privatly owned) experienced no operational improvements (quality and on-time delivery). The authors argued that those companies lacked in managerial resources and advanced management culture. Likewise, Bortolotti et al. (2013) found that JIT supply, single minute exchange die and cell manufacturing had a negative impact on lead time, on-time delivery and flexibility. These results were explained as a product of the high variability of demand within the companies surveyed. Their findings corroborate with literature that highlights the limitations of lean applications in non-repetitive environments.

More recent studies have highlighted the need to investigate how human resources can enhance the effect of lean on operational performance (Bonavia and Marin-Garcia, 2011, Clegg et al., 2013, Boscari et al., 2016, Vivares-Vergara et al., 2016). Companies that achieve the highest payoff from lean practices, are those that train workers and improve their employment security (Bonavia and Marin-Garcia, 2011). In addition, Boscari et al. (2016), highlighted the importance of teamwork, training and development, workforce adaptation/flexibility and culture on the success of implementation of lean practices.

~~The literature would appear to suggest that there are inconsistencies in the relationship between lean practices and performance. This could be explained through the application of contingency theory. This theory suggests that organisations do not exist in isolation, and are influenced by organisational and environmental factors. The implication is that firm performance will be maximised when there is a fit between an organisation's structure/processes and the external environment (Chavez et al, 2015). Applying contingency theory, the lack of an association between lean practices and performance may be explained by contextual differences. Most empirical studies that have considered contextual factors have been exploratory (Browning and Heath, 2009), with only some limited work looking at a firm's internal characteristics, such as size differences (Bayo-Mo~~

In summary, ILO helps to standardize operations and results in significant strategic benefits. According to Pakdil and Leonard (2014), lean production methods provide manufacturing organisations with a powerful competitive advantage due to efficient systems that "consume fewer resources, creating higher quality and lower cost as outcomes". A similar argument is made by (Belekoukias et al., 2014), who point to the operational improvements and resulting higher performance outcomes that lean techniques offer manufacturing organisations in contemporary, globalised and highly competitive markets.

Lean manufacturing principles do not only concern a company's technical operations but also its people. ILP has led to companies moving away from Tayloristic principles that encouraged the separation of "thinking from doing" through the centralisation of decision-making at the top of the organisational pyramid. On the contrary, lean manufacturing argues for the involvement of supervisors and production workers in the decision-making process through quality circles or other types of problem-solving groups and for raising their skills through training. Forrester (1995: p.22) highlighted the role that knowledge plays in ensuring synergy between lean and people practices: "The whole process becomes a more people-centred one, with employees becoming more involved and flexible. In its simplest terms lean production has to be a people-driven process, because only the employees can identify ways of improving the existing process or product".

Accordingly we posit the following hypothesis:

H1: ILP have a positive impact on operational performance.

2.2 Lean practices and the operational intellectual capital – operational performance relationship

The potential for a synergetic relationship between lean practices and dimensions of OIC can be addressed in the context of the KBV. According to the proponents of the KBV of the firm, knowledge is the most important strategic resource that provides and sustains competitive advantage (Grant, 1996, Eisenhardt and Santos, 2003). Companies need to develop value-creating strategies by managing the system of complementary resources (i.e. its knowledge base and lean practices). It could be argued that operations management programs and practices such as lean, might not entirely fulfil the requirements of competitive advantage (valuable, rare, hard to imitate or substitute). For example, the rare characteristic can be questioned: many companies have adopted lean practices and developed their own production system (i.e. Volvo production system) (Netland et al., 2015). However, previous research has shown that implementation of lean practices such as TQM, JIT, workforce development, automation, customer/supplier development and integration, enhances the operational performance making the companies more competitive (Netland et al., 2015, Boscari et al., 2016, Negrão et al., 2016).

Accordingly, using the KBV as the theoretical lens, we argue that when ILP are coupled with dimensions of OIC (which represents the company knowledge base), they both become a critical source for operational and business success. Wiengarten et al. (2013) highlighted that based on the RBV and OM literature, the long-term performance enhancing ability of operations programs such as lean, has not been fully explored. That can be explained by the fact that the impact of lean practices on performance might be complemented by other organisational dimensions or practices, resulting in a complementary performance enhancing relationship (Bortolotti et al., 2015). Teece (2014) defines complementary assets as resources that are required to gain the benefits associated with a strategy, a technology, or an innovation. While much of lean research suggests that there is a direct relationship between lean practices and operational performance, Teece's approach points out that companies would need to possess complementary assets to gain competitive advantage from the implementation of lean practices. Accordingly based on previous literature, KBV theory and the concept of complementarity, we argue that the performance impact of ILP can be enhanced through the OIC dimensions. The subsequent sections will explore the synergetic effects between each dimension of OIC and the lean practices.

2.2.1 Lean practices and human capital

Empirical evidence suggests that human capital (HUC) is a key antecedent of operational performance (Nyberg et al., 2014). The KBV, which draws upon the elements of the resource-based view (RBV) of the firm, has been used to identify HUC as a key variable in explaining why some companies outperform others (Prajogo and Oke, 2016). HUC is the knowledge, experience, professional skills and abilities in employees (Subramaniam and Youndt, 2005). If organizations invest in educating and training their employees, their professional skills and competence should increase, resulting in better individual and organizational performance. Snell and Dean (1992) have highlighted the role of human capital, specifically skilled human resources, in the implementation of new manufacturing practices such as advanced manufacturing techniques, just-in-time, and total quality management. Such programmes are quite complex to enact within an organisation, and require knowledgeable employees. Lee et al. (2011) examined the role of intellectual capital in implementing manufacturing process innovations (MPI). Initial findings suggested that HUC did not affect MPI, however when looking at the type of MPI (incremental versus radical) the results suggested that the greater the HUC, the higher the technical performance of radical MPI projects. Their findings concur with Subramaniam and Youndt (2005), who found that HUC had no direct impact on incremental innovation capability, while it had a significant impact on radical innovation capability.

Hitt et al. (2001) examined the direct and moderating effects of HUC on strategy and performance in professional service firms. Using cross-sectional (firms) and time series data (years), they found a curvilinear relationship between human capital and performance. Building human capital can be costly and it takes time to produce substantial benefits. However, continuing investments can reap greater benefits when done in conjunction with other practices, due to the synergies achieved. Furthermore, skilled workers tend to be more confident in their abilities than unskilled ones and are more likely to adopt technological change. When a new system or technology is being applied, they utilise their experience to solve the problems that relate to implementation. The positive impact of HUC on performance has also been highlighted by Crook et al. (2011). They argue that firms need to acquire and nurture the best and brightest human capital available and keep these “assets” in the firm. They also argue for additional research to explore the synergetic relationship between human capital and the use of high-performance work practices and their effect on performance. Thus, we hypothesise that the possession of knowledge, experience and professional skills and abilities in employees enables lean practices to achieve higher levels of operational performance.

H2: Manufacturing plants that are characterised by high levels of HUC gain higher operational performance benefits from ILP, as compared to plants with low levels of HUC

2.2.2 Lean practices and structural capital

The adoption of lean requires a vast amount of knowledge and information sharing. Workers that display knowledge of successful lean implementation are frequently identified as champions of implementation (Clegg et al., 2013). However, organisations from time to time lose the human capital when employees leave or move to a different company. As such, it is important that companies have systems or mechanisms to transfer knowledge from the individual to the organisational level. Lee et al. (2011) point out that isolated individual capabilities are not enough to effectively complete an innovative task (i.e. implementation of lean practices). Information must be exchanged, in order to strengthen the organisational learning capability and to fully leverage this resource.

The second form of OIC is structural capital (STC), which involves "the institutionalized knowledge and codified experience residing within and utilized through database, patents, manuals, structures, systems and processes, which can be conceptualized in terms of organizational processes and information systems" (Subramaniam and Youndt, 2005: p.451). According to Guerrero-Baena et al. (2015), structural capital is the frame and the glue of an organization because it provides the tools and architecture for retaining, packaging and moving knowledge along the value chain (Cabrita and Bontis, 2008). Sharing information is key to developing a learning culture, where workers can access cross-departmental knowledge (Wu, 2008). In order to facilitate this, knowledge must be deemed valuable and companies must focus on the quality of the information shared, rather than quantity. Ferdows (2006) highlighted the need for the proper codification of information in order to facilitate its movement between organisational units. This results in the standardisation of procedures and processes which are key features in lean management (Spear and Bowen, 1999). In contrast, Secchi and Camuffo (2016) propose a counterintuitive view that in lean programs, the codification of knowledge may decrease transfer effectiveness by inhibiting local adaptation. Also, standardisation of work can lead to reduced work autonomy, increase monotony and stress. On the other hand, Losonci et al. (2011: p.31) state that in lean production "workers have more freedom in dividing their work within their group, and they become responsible for the level of quality that they provide, for improvements in that regard, and for other work-related issues". Grove et al. (2010) investigated a 13-month lean implementation in National Health Service (NHS) primary care health visiting services, specifically focusing on standardisation and identification of value adding activities. Their findings suggest that the lean implementation demonstrated significant waste reduction in the health service. For example, standardisation enabled a reduction in the variation in day-to-day activities performed by clinical staff and allowed them to focus on value adding activities.

Tu et al. (2006) and Huang et al. (2008) found that information sharing and internal learning have a positive impact on successful implementation of manufacturing practices. As such, STC enables workers to access valuable complementary expertise, thereby leading to a more successful implementation of lean practices.

Thus, we propose the following hypothesis:

H3: Manufacturing plants that are characterised by high levels of STC gain higher operational performance benefits from ILP, as compared to plants with low levels of STC

2.2.3 Lean practices implementation and social capital

The third form of OIC is social capital (SOC) and is defined as "the knowledge embedded within, available through and utilised by interactions among individuals and their networks of interrelationships" (Subramaniam and Youndt, 2005: p.451). In comparison to structural capital, which requires formal process and procedures, social capital does not need any predetermined rules (Lee et al., 2011). According to Zhang et al. (2015), social capital reflects the knowledge that develops from formal and informal interactions among employees, which enables cooperation and the formation of knowledge exchange mechanisms.

Informal interactions among employees, allows them to reach common goals and to collaborate across functional boundaries, enabling the development and implementation of new practices (Lee et al., 2011). When employees are able to openly discuss problems and issues, they are more likely to embrace knowledge about latest process developments and try new practices without worrying about making mistakes (Kang and Snell, 2009). Youndt et al. (2004) state that social capital helps employees to have common expected outcomes of process innovations and motivates them to find solutions together, enabling a company to introduce new processes frequently. Moreover, the accessibility of people in different functions facilitates interactions that lead to a common understanding of the production system as a whole, rather than being function based (Zhang et al., 2015).

Prior empirical research has shown the important role that organisational culture plays in the implementation of new programmes or practices (Danese et al., 2017, Losonci et al., 2017). Positive and supportive organisational culture tends to amplify the "togetherness" element of the workforce. This can be regarded as an aspect of social capital because it promotes trust and collaborative relationships among workers (Behara et al., 2014).More recently, Matthews and Marzec (2012) found empirical support for social capital having a positive impact on quality management, project management, new product development and supply chain management. Similarly, Yuan et al. (2009) established that investments in social capital is an important precondition to enhanced group learning and performance. When investing in lean practices, a key element is employee involvement. Employees are encouraged to express their opinions and feel secure in suggesting process improvements. Previous studies have labelled this type of behaviour as "an open communication climate" (Tu et al., 2006) or "team psychological safety" (Lee et al., 2011). Any sort of new system or practice that is being adopted will require and benefit from the support of top management. Employees will therefore be less likely to fear failure and will be more willing to take risks and be innovative throughout the implementation process. When employees are encouraged to share errors/mistakes and openly seek resolution, the new system or practice is more likely to be installed efficaciously. Having a strong collaborative culture can lead to successful implementation of lean (Bortolotti et al., 2015). Thus, we posit:

H4: Manufacturing plants that are characterised by high levels of SOC gain higher operational performance benefits from ILP, as compared to plants with low levels of SOC

Accordingly, this study examines the effects of ILP on operational performance by considering the moderating role of individual dimensions of OIC. Figure 1 depicts the proposed research framework based on the theoretical advancements presented.

-- Insert Figure 1 about here --

3. Methodology

3.1 Sample and procedures

The empirical data used for this study was drawn from the fifth round of the Global Manufacturing Research Group (GMRG) survey project, collected between 2011 and 2014. The Global Manufacturing Research Group (GMRG) (www.gmrg.org) is an international community of researchers who are rigorously studying the improvement of manufacturing supply chains worldwide. The instrument was designed to assess and improve manufacturing and supply chain practices worldwide and has been in use since 1985 in many studies (Whybark, 1997). The survey has been conducted in several rounds and in each round, a common questionnaire for all countries is developed based on well-grounded theories, group members meetings, feedback from previous rounds and industrial interviews (Li et al., 2018). The questionnaire has been translated and back-translated by researchers in each country, in order to ensure equivalency, validity and reliability of the translated surveys (Kull et al., 2014). The unit of analysis is the manufacturing site or plant, and all data are collected from plant managers as key informants within that site, who often consult others in their firm. These managers are targeted since they are deemed to possess a comprehensive knowledge of the plant's operations, in addition to having insight into related functions. The managers are advised to solicit input from other functions, such as marketing and finance, when required.

In order to ensure comparable samples were collected from each country, detailed information related to the questionnaire administration was provided. Each data collector received a GMRG start-up package that contained the questionnaire, the data gathering sheet (where data has to be stored), the validation sheet (where data quality can be assessed) and the methodology sheet (which described how data collection has been developed). The data collected from various countries were grouped by a central data manager for incorporation into the central database. Prior to inclusion, each data collector performed a check of the quality of the data gathered in terms of incomplete questionnaires, missing data, unreliable answers (i.e. answers outside the provided scales) and the country codes. Data was collected by individual members of the GMRG, who are requested to apply the most appropriate approach and the most suitable population frame depending on the country-specific circumstances (Whybark, 1997).This flexibility is afforded to the researchers owing to the complexity and length of the questionnaire, often requiring the key respondent to consult with other individuals within the firm, or the compilation of historical data and the calculation of indices. Most questionnaires were administered during an on-site personal interview (43%), followed by internet completion (29%) and mail surveys (23%) (Schoenherr and Narasimhan, 2012).

The questionnaire consists of one core module (providing constructs related to demographics and competitive environment) plus four other modules on supply chain management, sustainability, and innovation and facility culture. In addition to the core module of the survey, the data gatherers were free to select specific modules that they were interested in. The fifth round of the GMRG survey had 987 respondents in total, however given the focus of this study on the interaction between OIC components and ILP, we only used data where survey respondents completed the modules which contained our variables of interest. This reduced our sample size to a total of 528 plant responses. Thus, given the extensive coverage over 10 countries from all the major continents ensures that the GMRG data is appropriate for generalising about the synergetic effects between ILP and OIC dimensions.

Table I provides an overview of the dataset used in terms of country of origin, company size and industry.

--- Insert Table I About here --

In order to test for non-response bias, the responses from early and late respondents were compared on selected variables (i.e. ILP, performance measures and OIC variables) using independent samples t-tests (Schoenherr and Narasimhan, 2012). This test assumes that late respondents are used as proxy for non-respondents (Armstrong and Overton, 1977). The results show that there is no statistically significant difference between these two groups, indicating that the potential non-response bias is not evident. Given the limitations of this test (Wright and Armstrong, 2008) and the fact that we could not contact individuals that did not respond at all (due to unavailability of this information), we decided to further corroborate this assessment, by testing for item non-response bias (Wagner and Kemmerling, 2010). This approach can be compared to the more rigorous method of contacting non-respondents. Independent samples t-tests were applied to compare questionnaires from individuals that provided answers to the all survey questions to those that only partially completed the survey (with the latter serving as a proxy for non-respondents and not being included in the final sample). The results yielded non-significant differences between complete and incomplete surveys, further reinforcing that non-response bias is not a serious concern.

3.2 Measures: reliability and validity

To measure ILP, respondents were asked to indicate the extent to which their plant has invested resources (money, time and/or people) in the previous two years in these initiatives. The measures related to the investments in lean practices have been used and tested in previous research. Our data reflect the extent that lean practices proposed by Shah and Ward (2007) are perceived in the plant as follows: quality management programs (i.e. TQM, six sigma) (Cua et al., 2001), cost reduction programs (i.e. target costing) (Modarress et al., 2005), manufacturing lead time reduction programs (Jayaram et al., 2008, Kull et al., 2014), planning/scheduling processes and methods (Bortolotti et al., 2015), processing technologies (e.g. automation, advanced manufacturing technologies) (Narasimhan et al., 2006), flexible workforce (Jayaram et al., 2008, Bortolotti et al., 2015), supplier development (Narasimhan et al., 2006), workforce training and development (Bortolotti et al., 2015), integrating manufacturing and design processes (Narasimhan et al., 2006, Jayaram et al., 2008), plant information flows automation (Kull et al., 2014), customer service, customer process integration and supplier process integration (Narasimhan et al., 2006, Bortolotti et al., 2015). All the lean practices measures used have been identified as part of lean bundles the current extensive literature reviews of Jasti and Kodali (2015) and (Negrão et al., 2016).

The operational performance construct was adopted from Melnyk et al. (2004), Cua et al. (2001) and was measured across the selected dimensions of cost, quality, delivery and flexibility. The variable is a second order construct, with no modification indices used, that measures firms 'operational capabilities compared to major competitor(s) on the 7-point Likert scale (1- far worse to 7- far better). OIC was conceptualised in dimensions of social capital (4 items), structural capital (4 items) and human capital (4 items). The items for the human, social and structural capital were developed based on studies by Menor et al. (2007) and Subramaniam and Youndt (2005). The respondents were asked to indicate their level of agreement with multiple statements on a scale of one (strongly disagree) to seven (strongly agree). Two control variables were added: plant size and industry type. Shah and Ward (2003) suggest that large plants are likely to invest in lean practices more extensively compared to small plants. In addition, ILP are particularly relevant to certain industry types, such automotive, given the repetitive processes and high volumes (Hines et al., 2004). Hence plant size and industry type were included in order to increase the generalisability of this study.

4. Results

4.1 Scale validity

Confirmatory factor analysis was used to simultaneously validate the measures of all variables used in the study. The results are presented in Table II. Convergent validity was assessed by comparing the items' coefficients and their standard error. Results indicate that each coefficient was greater than twice its associated standard error (Farrell and Rudd, 2009). Cronbach alpha values have been calculated to test the reliability (internal consistency) of the proposed latent variables. All values in Table II, column 1 are above the commonly used cut-off value with a minimum of 0.7 indicating reliable measures (Raykov and Marcoulides, 2011).

--Insert Table II About here—

A comparison of the goodness-of-fit values against the Hu and Bentler (1999) thresholds indicate that this model is satisfactory (See table II for details). In addition, the ratio of chi-square to degrees of freedom of 2.209 (χ^2/df) is satisfactory (Hooper et al. (2008)). Subsequently, it can be concluded that the measurement items represent the underlying factor structure in a conclusive manner (Wang and Wang, 2012).

4.2 Convergent reliability and inter-factor correlations

Composite reliability statistics indicated strong construct reliability in each case; all values are well above 0.7 (Fornell and Larcker, 1981). The results established convergent validity and unidimensionality for each construct, as all item loadings (lambdas) are highly significant (all t-values are >2.0) (See Table II). The results also indicated acceptable discriminant validity for the measures at both the construct and item levels. We interpret these results as strong, especially given the multi-country, multi-industry and highly varying size of the organizations represented in this data set. It is also customary to report inter-item correlations. This is presented in Table III. Discriminant validity was confirmed through testing inter-factor correlations. Results indicate adequate inter-factor correlations (Schreiber et al., 2006)

--Insert Table III About here --

4.3 Common method variance

Common method variance is a crucial question when both the dependent and focal explanatory variables are perceptual measures derived from the same respondent (Conway and Lance, 2010). The post hoc Harman one-factor analysis was performed and one-factor analysis accounts for only 30.696% % of variance (Podsakoff et al., 2003). The results of the test, provide evidence that common method variance does not appear to pose a serious threat to our study.

4.4 Measurement equivalence

Finally, since the dataset used in this study was collected in multiple countries, the issue of measurement equivalence had to be addressed. More specifically, we examined whether or not the constructs via their related scales are invariant across countries (Malhotra and Sharma, 2008). Measurement equivalence refers to whether or not measurement items, under varying conditions and phenomenon, yield the same attributes. It is critical to assess measurement invariance across groups in order to be able to make valid scientific claims and conclusions (Malhotra and Sharma, 2008). Only if measurement equivalence is ensured across countries then the collected datasets can be either combined or compared with each other. A number of recent studies have confirmed measurement equivalence in the GMRG dataset through various tests (e.g. Schoenherr and Narasimhan, 2012; Wiengarten et al., 2011).

4.5 OLS regression analyses

To test the proposed model, we used three OLS regression analyses (Wiengarten et al., 2013, Chavez et al., 2015, Durach and Wiengarten, 2017). The analysis was conducted in three separate models reflecting the three interaction terms (level of ILP and social capital; level of ILP and human capital and level of ILP and structural capital). In the first step of the OLS analysis, the control variables, industry type and plant size were introduced. In the second step, the level of ILP and moderators: social capital (Model I), human capital (Model II), and structural capital (Model III), were introduced. In the third step, the interaction terms were added (Model I: ILP and SOC; Model II: ILP and HUC; Model III: ILP and STC). Prior to carrying out the OLS analysis the data was checked in terms of linearity and multicollinearity (Kennedy, 2003). Firstly, the variance inflation factors (VIFs) were calculated and are included in table IV. The resulting VIFs indicate that multicollinearity is not apparent.

--Insert Table IV About here--

In H1 it was hypothesised that ILP have a significant positive impact on operational performance. Previous empirical studies showed mixed results for lean practices implementation on operational performance. In terms of contingency theory, our analyses reveal that both industry type and plant size had no significant effect on operational performance. The results presented in Table IV indicate that ILP and the dimensions of OIC do significantly improve operational performance. This finding concurs with Menor et al. (2007) who found that investments into OIC augment operational performance. Accordingly, we found support that all three dimensions of OIC have a positive impact on operational performance.

In H2, H3 and H4 we posited that ILP have a stronger positive impact on operational performance when combined with high levels of investments in social, human and structural capital. To analyse the synergetic effects between the ILP and OIC, interaction terms were calculated by adding the two-way interaction term to the OLS Models I, II and III.

In model I, the addition of the two-way interaction term contributed to a significant change in the variance explained (R2 adj. = 0.323, $p = 0.000$), however the interaction term was not significant ($B = 0.071$, $p = 0.052$). The results reveal no synergetic effects between the ILP and human capital. For model II adding the two-way interaction term contributed to a significant change in the variance explained (R2 adj. = 0.292, $p = 0.000$), and the interaction term was significant ($B = 0.109$, $p < 0.05$). To interpret this finding the significance of the slopes were calculated at low (one standard deviation below the mean) and high (one standard deviation above the mean) levels of STC (Preacher et al., 2006, Dawson, 2014). The results revealed that ILP were strongly associated with higher operational performance when the levels of STC were high, than when the levels of STC were low (see Figure 2). In other words, ILP have a higher payoff rate when the firm is also increasing the level of structural capital. Accordingly, there is evidence of synergetic effects between ILP.

Finally, in OLS Model III the addition of the two-way interaction term contributed to a significant change in the variance explained (R2 adj. = 0.361, $p = 0.000$), and the interaction term was significant ($B = 0.076$, $p < 0.05$). To interpret this finding the significance of the slopes were calculated at low (one standard deviation below the mean) and high (one standard deviation above the mean) levels of SOC (Preacher et al., 2006, Dawson, 2014). The results revealed that ILP were strongly associated with higher operational performance when the levels of SOC were high, than when the levels of SOC were low (see figure 3). In other words, ILP have a higher payoff rate when the firm is also increasing the level of social capital. Thus, we also found evidence of synergetic effects between ILP and SOC.

--Insert Figure 2 About here---

--Insert Figure 3 About here---

4. Discussion and implications

The objective of this study was to empirically test if the operational intellectual capital (in terms of human, structural and social) contribute to the efficacy of ILP. Although partial support was found for the hypothesised relationships (three out of four hypotheses were supported), our findings provide a significant contribution to lean management theory in adopting a knowledge-based view of the firm. The significance of these contributions is discussed below.

In exploring the research question of this study, we have made a number of theoretical contributions. The literature review has identified several studies that investigated the impact of lean practices on operational performance (Chavez et al., 2015, Boscari et al., 2016, Danese et al., 2017). Our study further underpins the argument that lean practices investments lead to higher operational performance, specifically in terms of cost, quality, flexibility and delivery dimensions. This finding is compatible with the "cumulative" perspective (Ferdows and De Meyer, 1990) which suggests that high operational performance is achieved by pursuing multiple competitive priorities. Our results suggest that ILP enable companies to outperform their competitors on multiple operational performance dimensions, rather than focusing on individual performance objectives.

Companies introduce innovative practices such as lean practices in anticipation of improving performance. Negrão et al. (2016) highlighted that most studies of lean practices focus on testing their impact on operational performance, but that very few attempt to explain how this impact can be augmented. Our study addresses this gap and provides a plausible explanation of this gap. We argue that OIC, which represents the organisational learning capability, can enhance ILP. Our findings of moderation effects (for two out of three OIC dimensions) reinforces the role of OIC as a mechanism that enhances operational performance in ILP. Accordingly, our research offers an additional important contribution to the lean literature by testing the moderating role of OIC.

This study also contributes to the intellectual capital literature by providing insights into the individual effects of human, structural and social capital on operational performance (Wang et al., 2014, Prajogo and Oke, 2016, Zhang et al., 2017) and how these dimensions can be used to enhance the efficacy of lean practices (Hadid et al., 2016). We did not find evidence of interaction effects between the ILP and human capital. This is somewhat surprising, as human capital, which represents knowledge, experience and professional skills, would be expected to act as a key variable in rolling out a lean production system. Our findings concur with other studies, in that HUC positively impacts on operational performance (Wang et al., 2014, Prajogo et al., 2016); however no empirical support was found for an enhancement effect on the efficacy of ILP. A possible explanation for this result is provided by considering the findings of Subramaniam and Youndt (2005) who empirically tested the impact of human capital on the innovation capabilities and found no direct impact on incremental innovation but a significant impact on radical innovation. Accordingly, we posit that ILP result in incremental innovation capability, which "build on and reinforce the applicability of the existing knowledge base" (Abernathy and Clark, 1985: p.5). The implication is that human capital will not enhance the efficacy of incremental improvements, for example lean practices implementation. Another explanation could relate to the maturity level of lean investments. In our study we did not measure the degree of lean maturity; however if companies are just starting to invest in lean practices, then we would expect human capital to play an important role in the efficacy of ILP. As the lean practices mature, the work methods become standard and routine-based, thus reducing the synergies between HUC and ILP.

Furthermore, we found that structural and social capital have a positive impact on operational performance and enhance the efficacy of lean practices (Hsu and Wang, 2012, Sparrow and Otaye-Ebede, 2014). Both, STC and SOC, acted as moderators in the lean practices and operational performance relationship. These results provide further understating of the effects of STC and SOC on performance (Subramaniam and Youndt, 2005, Menor et al., 2007) as well as their augmentation role in lean investments. Hence, researchers could consider both the direct and moderating effects of the OIC when investigating lean investments.

Structural capital has been conceptualised in terms of the institutionalised knowledge and codified experience residing within a company. This allows knowledge to move across the value chain and results in the development of standardised processes and procedures that are shared across departmental units. The STC creates the characteristics of a self-directed learning environment and enables companies to replicate knowledge embedded in practices by utilising physical organization-level repositories such as databases, archives and SOPs. Replication is a key element of lean production systems that enhances standardisation (Bonavia and Marin-Garcia, 2011). Having a standardised procedure/ process creates a starting point for companies to continuously improve. It can reduce the cost and time of the implementation process. Secchi and Camuffo (2016) conducted a longitudinal study of the process of rolling out lean production systems. Their findings offer a counterintuitive view on the effectiveness and efficiency of lean implementation and point out that "lean roll-outs are learning and discovery processes where paradoxically codification and structural differentiation are not necessarily conducive to better outcomes" (Secchi and Camuffo, 2016: p.82) This concurs with the view that ambidextrous learning is derived from intellectual capital architectures as a result of unique configurations of the different forms of intellectual capital (Kang and Snell, 2009). Our study did not assess the ambidextrous learning through configurations of OIC; however we found empirical evidence that STC through enhanced knowledge replication increases the efficacy of ILP. We argue that companies that share valuable knowledge and promote internal learning will achieve higher operational performance. As such, STC enables workers to access valuable complementary expertise, thereby leading to more successful ILP (Tu et al., 2006, Huang et al., 2008).

Social capital, on the other hand, does not rely on formal processes and procedures or any predetermined operating rules. We defined social capital as the knowledge available through interactions among individuals, degree of accessibility, and openness of communication. Recent studies have highlighted the role of social capital and organisational culture in increasing operational performance (Danese et al., 2017, Losonci et al., 2017, Wiengarten et al., 2017). This study provides a deeper understanding into its role as we specifically investigated the combined impact of SOC and ILP on operational performance. Our results show that the impact of ILP on operational performance is increased in the presence of SOC. Previous studies established the role of SOC in improving mass customisation and product innovation capabilities (Zhang et al., 2015, Wiengarten et al., 2017). We thus contribute to this area of the literature by confirming the SOC's pivotal role for the efficacy of ILP.

From a managerial standpoint, this study provides guidelines for managers on how to leverage OIC to enhance the return of ILP. We argue that firms consider investing in OIC to increase their operational performance. Human capital development is important, especially when companies seek to conduct radical improvements. Focusing on job enlargement and enrichment will create knowledge workers, that would be better equipped in dealing with innovative projects. Training programmes should be developed to share best practices and dispense knowledge through the organisation.

When companies select, recruit, train and reward employees, they should focus not only on their individual skills or functional expertise, but also on their ability to share it with other team members, in order to create a collaborative culture. Acceptance of knowledge from others is another important aspect of change implementation (Beer and Eisenstat, 2000). Companies need to design proper channels of knowledge collection and dissemination (Ferdows, 2006). This is where structural capital plays an important role in enhancing ILP. Our results reveal that STC positively impacts operational performance and companies ILP have a higher payoff rate in terms of operational performance, when the company is also increasing their STC levels. These findings corroborate with Tu et al. (2006) and highlight the need for firms to develop an open learning culture, where workers can access cross-departmental knowledge as well as knowledge from external partners (suppliers and customers). This type of structural relationship leads to better coordination and implementation of lean practices across departments and companies.

Our findings provide strong evidence of the importance of social capital to enhance the efficacy of ILP. Sawhney et al. (2010) state that the reason why not all companies experience improved operational performance from lean practices, is that they do not focus on the sustainability aspect of change, specifically referring to the lack of know-how. In this regard we emphasise that social capital is an important enabler for employees to share ideas and cooperate in know-how creation. The degree of accessibility of people, allows them to comfortable approach one another and discuss problems and issues openly. Inherently, it creates psychological safety and provides a strong foundation for knowledge exchange and combination within a firm. Social capital impacts the ILP, therefore managers need to encourage informal conversations among employees in the plant as a form of sharing knowledge and organise events where people can openly discuss their experiences. These events can therefore act as catalysts in enhancing interrelationships and contribute to successful lean practices implementation.

5. Limitations, further research and conclusion

This study has some limitations. Firstly, we suggest further refining the measurement items of OIC to holistically capture the dimensions of operational intellectual capital. Secondly, we investigated the impact of ILP on operational performance; however, the use of additional performance measures, such as financial and market related performance could be merited. Thirdly, the existing literature on lean practices does not address the innovativeness of lean practices and how these practices should be managed in different ways. Thirdly, our analysis provides limited theoretical insights into how to use OIC resources differently given how far a company has progressed on its lean journey. It may very well be the case that if a company is new to lean implementation, then this would be viewed as radical innovation and as such, human capital would play an important role in its implementation. If the company has progressed on its lean journey, then the STC and SOC might provide stronger support in increasing the efficacy of lean practices. Thus, further investigation of the relationship between the maturity level of the lean practices and the level of investments in OIC is worthy of consideration. Fourthly, our study did not consider the interrelationships among HUC, STC and SOC. Future studies could investigate how the interaction between these dimensions, yield the highest impact on the efficacy of ILP. In addition, other contextual variables should be used in order to see if the impact of OIC on the efficacy of ILP varies across them. Finally, our sample framing design is likely to be non-random. Although we have the benefits of a large-scale cross-country dataset, the data collection is subject to this limitation, which needs to be considered when interpreting the results.

Overall, this study extends our understating of how companies enhance the effect ILP have on operational performance. We examined the effects of ILP on operational performance by considering the moderating role of OIC. To test our hypotheses, we used three OLS regression analyses. The analysis was conducted in three separate models reflecting the three interaction terms (level of ILP and human capital; level of ILP and structural capital and level of ILP and social capital). Our results confirm the impact of social and structural capital on ILP and raising operating performance, hence hypotheses H2 and H3 are confirmed. Human capital interaction with ILP on operational performance did not show a significant effect.

This paper makes three key contributions to operations management literature. Firstly, this study extends our understanding of how some organisations achieve superior performance by leveraging individual dimensions of OIC. Secondly, we add valuable insights to the lean literature by testing the synergetic effects between elements of the operational intellectual capital and the ILP (Sparrow and Otaye-Ebede, 2014). The results shed further understanding of the complex relationship between ILP and operational performance. Thirdly, from a practical perspective our research offers managers empirical evidence related to the effect of knowledge management on operational performance. Specifically our study highlights how the individual elements of the OIC can be used to augment operational performance generated though ILP (Wu, 2008, Wang et al., 2014).

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Table I. Sample descriptive

Country	n	%
Australia	18	3.4
China	30	5.7
Croatia	100	18.9
Hungary	28	5.3
India	58	11.0
Ireland	29	5.5
Poland	73	13.8
Taiwan	40	7.6
USA	82	15.5
Vietnam	70	13.3
Total	528	100.0

SIC code	n	%
Food and kindred products	59	11.2
Tobacco products	1	0.2
Textile mill products	16	3
Apparel and other finished products	29	5.5
Leather and leather products	5	0.9
Lumber and wood products	22	4.2
Paper and allied products	21	4
Printing. publishing and allied industries	9	1.7
Petroleum refining	5	0.9
Chemicals	25	4.7
Rubber	41	7.8
Primary metal	25	4.7
Fabricated metal products	51	9.7
Machinery and computer equipment	40	7.6
Electronic and electrical equipment	50	9.5
Measuring, analysing and controlling instruments	7	1.3
Motor vehicles	18	3.4
Other transport equipment	12	2.3
Furniture and fixes	15	2.8
Stone, clay, glass	19	3.6
Miscellaneous	58	11
Total	528	100

No of Employees	n	%
<50	127	24.1
>=50 <=249	234	44.3
>=250	167	31.6
Total	528	100

Table II. Confirmatory factor analysis of the complete model

		Factor loadings	S.E.	C.R.	P
Investments in Lean Practices **CR** 0.898 **AVE** 0.405 Alpha 0.900	Quality management programs (e.g. TQM, Six-Sigma)	0,534			
	Cost reduction programs (e.g., Target Costing)	0,537	0,073	11,745	***
	Manufacturing lead time reduction programs	0,666	0,089	10,947	***
	Planning/scheduling processes and methods	0,696	0,09	11,261	***
	Processing technologies (e.g. FMS, automation)	0,616	0,09	11,616	***
	Flexible workforce	0,578	0,091	10,022	***
	Supplier development	0,608	0,098	10,461	***
	Workforce training and development	0,531	0,081	9,516	***
	Integrating manufacturing and design processes	0,705	0,1	11,243	***
	Plant information flows automation	0,669	0,101	10,924	***
	Customer service	0,641	0,083	10,619	***
	Customer process integration	0,744	0,1	11,608	***
	Supplier process integration	0,701	0,098	11,286	***
Operational Performance **CR** 0.845 **AVE** 0.589 Alpha 0.868	Cost	0,497			
	Quality	0,704	0,158	7,404	***
	Delivery	0,857	0,221	8,624	***
	Flexibility	0,938	0,216	8,613	***
	Labour unit costs	0,718			
	Total product unit costs	0,881	0,081	15,178	***
	Raw material unit costs	0,65	0,061	13,415	***
	Product performance	0,636			
	Product conformance to customer specifications	0,855	0,086	13,653	***
	Pre-sales service and after sales service	0,767	0,082	13,377	***
	Delivery speed	0,874			
	Delivery reliability	0,861	0,049	21,532	***
	Response to changes in delivery due dates	0,771			
	Production volume flexibility (increase/decrease volume)	0,806	0,067	15,778	***
	Production variety flexibility (increase/decrease product mix)	0,678	0,058	15,653	***
Social Capital	There is ample opportunity for informal conversations among employees in the plant.	0,841			

CR 0.877 **AVE** 0.646 Alpha 0.876	Employees from different departments feel comfortable calling each other when need arises.	0,918	0,04	26,114	***
	People are quite accessible to each other in the plant.	0,826	0,045	22,531	***
	We are able to discuss problems and tough issues openly.	0,594	0,047	15,626	***
Structural Capital **CR** 0.892 **AVE** 0.676 Alpha 0.895	Processes in our plant are well defined.	0,707			
	We usually follow the sequence of written procedures and rules.	0,738	0,064	19,171	***
	Much of this plant’s knowledge is contained in manuals archives or databases.	0,905	0,074	19,145	***
	Standard operating procedures are in place.	0,916	0,072	19,638	***
Human Capital **CR** 0.899 **AVE** 0.689 Alpha 0.894	Every employee in this plant has useful experience.	0,846			
	Employees in this plant are experts in their particular jobs and functions.	0,797	0,048	21,264	***
	Employees in this plant are considered among the best people in the organization.	0,868	0,044	23,244	***
	Employees in this plant are highly skilled in their respective jobs.	0,808	0,048	20,392	***
χ2=2.209<3, GFI=0.888, NFI=0.892, IFI=0.938. CFI=0.937, all ≈ 0.9, REMSA=0.048 has to be <0.05, PCLOSE = 0,828 has to be close to 1					

Table III. Inter-factor correlations

Constructs	Mean	(1)	(2)	(3)	(4)	(5)
Operational performance (1)	2.69	0.589 (0.347)				
Investments in Lean Practices (2)	4.34	0.475**	0.405 (0.164)			
Human Capital (3)	5.08	0.507**	0.440**	0.689 (0.475)		
Structural Capital (4)	3.88	0.450**	0.432**	0.681**	0.675 (0.456)	
Social Capital (5)	5.22	0.486**	0.323**	0.639**	0.607**	0.646 (0.418)

Value on the diagonal is the AVE and its square root in brackets; **Correlation is significant at the .001 level (2-tailed)

Table IV: OLS analysis for moderation effects

	Model 1 Human capital	Model 2 Structural capital	Model 3 Social capital
Variable			
Step 1. Control variables			
Industry Type	0.012 (0.870)	0.012 (0.870)	0.012 (0.870)
Plant Size	-0.010 (0.821)	-0.010 (0.821)	-0.010 (0.821)
Step 2. Independent variables			
ILP	0.471**	0.471**	0.471**
Step 3. Moderators			
HUC	0.471**		
STC		0.295**	
SOC			0.359**
Step 4. Interactions			
ILP * HUC	0.071(0.052)		
ILP * STC		0.109(0.004)	
ILP * SOC			0.076(0.039)
Step 1 Rsquare Change/Sig.	0.000 (0.940)	0.000 (0.940)	0.000 (0.940)
Step 2 Rsquare Change/Sig.	0.218 **	0.218 **	0.218 **
Step 3 Rsquare Change/Sig.	0.107 **	0.069 **	0.114 **
Step 4 Rsquare Change/Sig.	0.005 (0.052)	0.011 (0.004)	0.005 (0.039)
Max VIF	1.304	1.331	1.190
R	0.574	0.546	0.581
Adjusted R2	0.323	0.292	0.361
Sig	0.000	0.000	0.000
Outcome	**H2 not supported**	**H3 supported**	**H4 Supported**

Notes: **Significant at the 0.01 level

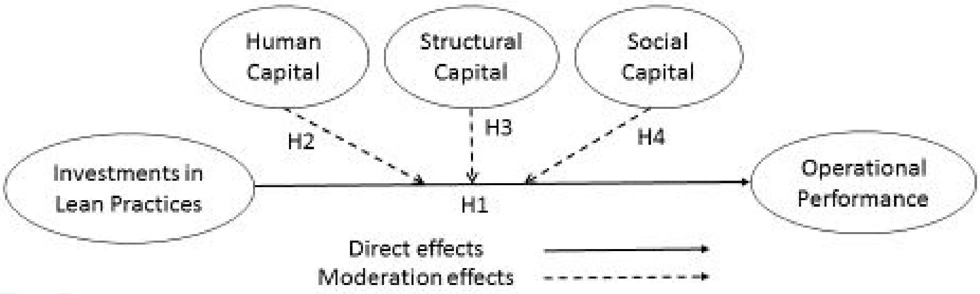

Figure 1. Research framework

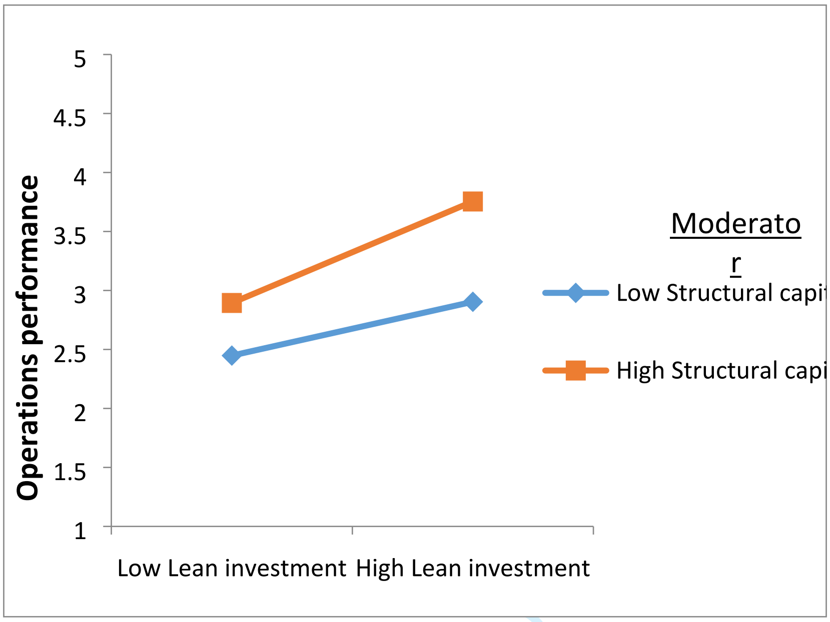

Figure 2. Moderating role of STC

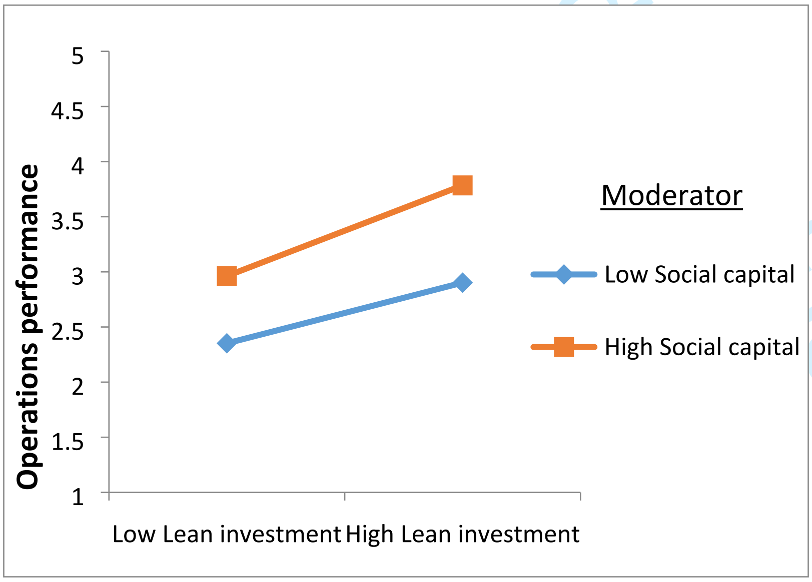

Figure 3. Moderating role of SOC